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(71) Applicant: OTIS ELEVATOR COMPANY
Farmington, CT 06032 (US)

(72) Inventors:
- Leach, Robert B.
New Britain, Connecticut 06053 (US)
- Youla, Jean
Brooklyn, New York 11223 (US)
- Slabinski, Chester J.
New Hartford, Connecticut (US)

(74) Representative: Tomlinson, Kerry John
Frank B. Dehn & Co.
European Patent Attorneys
Imperial House
15-19 Kingsway
London WC2B 6UZ (GB)

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(54) Capacitive sensing, solid state touch button system

(57) A solid state touch or control button assembly (10), with no moving button parts and operated by capacitive sensing by monitoring the phase shift of a signal applied to the face of the button, and having a constant pressure operation. If the button surface is touched, the capacitance is changed and sensed, causing the electrical or electronic function controlled by the touch button to be activated (or deactivated, depending on the design, or otherwise altered). LEDS then are activated, providing visual feedback to the button pusher through a light ring (2A) surrounding the button surface (1). False activations by noise transients, including those due to EMI, RFI and other environmental fluctuations, are avoided by delaying the activation of the button by an appropriate amount of time, such as, for example, of the order of about one hundred (100 msec.) milliseconds.

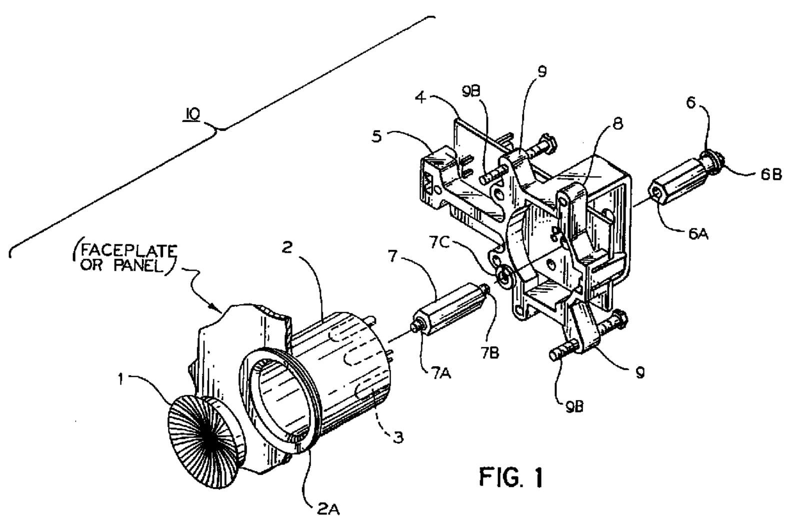

FIG. 1

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Description

The present invention relates to touch buttons typically used to activate or deactivate or otherwise control some electrical or electronic function, such as signaling, when touched typically by a human operator touching or "pushing" on the button with a finger. The invention more particularly relates to a solid state touch button system with no moving parts operated by capacitive sensing, which can be used in many different applications, including, for example, as a touch or push button for elevator car calling or control.

There is a need for a reliable button that does not use or need moving parts or mechanical contacts, to be used in, for example, elevator applications. It is desirable that such a button be aesthetically pleasing in appearance and use, highly reliable, low in cost and not be activated by extreme environmental changes.

It is known that the human body has some amount of capacitance to ground. A basic, previously known concept or approach is to monitor a button face for capacitance to ground, and, if a certain amount (or greater) capacitance is present, to activate the button.

In the present invention, this monitoring of the button surface is accomplished by monitoring the phase shift of a signal applied to the face of the button.

However, due to the residual impedance of the button and the presence of external influences, the steady state phase shift of the button can fluctuate. Such external influences include, for example, temperature changes, cleaner residue build-up and other deposits or extreme environmental changes, etc. This fluctuation has the potential to falsely activate a button, which is based on the monitoring of phase shift, although in fact no human operator is touching the button.

US-3761736 discloses a switch comprising an insulated electrode whose capacitance can be changed. The electrode is coupled to a bridge circuit which has a delayed self-balancing action.

DE-3117185 discloses a touch switch circuit which is not affected by temperature changes by means of a self-regulating circuit comprising a differential amplifier with negative feedback.

A distinguishing characteristic of such above mentioned fluctuation is that it would occur slowly over a period of time relative to a phase shift induced by the presence of a person. To avoid this problem, according to the preferred "constant pressure" embodiment, the steady sate phase shift fluctuation is compensated by setting a threshold for activation higher than any normal fluctuations.

Another potential source of false activations of such a button are phase shifts induced by transient noise. These potential transients include, for example, electromagnetic interference (EMI) and radio frequency interference (RFI).

A distinguishing characteristic used in the invention to help prevent false activations caused by transient noise is that such noise would not last for a long period of time relative to the interaction time with a person. Activations due to transient noise thus are avoided in the invention by delaying the activation of the button for a certain minimum period of time.

Thus the present invention is directed to a reliable button that does not need, and preferably does not use, moving parts or mechanical contacts and can be used in, for example, elevator applications.

According to the present invention, there is provided a capacitive sensing touch button for controlling a function, said button comprising:

a button surface member for receiving a reference signal, said button surface member outputting a signal shifted in phase, relative to the reference signal, upon contact of said button surface member by a user;

an oscillator to provide the reference signal to said button surface member, said oscillator having a predetermined duty cycle;

a phase shift to pulse width converter to convert the phase-shifted signal into a pulse width based on the amount of the phase shift relative to the reference signal;

means for avoiding false activation of the controlled function due to residual impedance and/or external influences at said button surface member, said avoiding means receiving the output of said phase shift to pulse width converter;

characterised in that:

said avoiding means further comprises an integrator to convert the pulse width into a dc voltage; and

a level detector to output a control signal when the dc voltage is greater than a predetermined threshold voltage;

and in that said button further comprises delay means to receive an output signal of said avoiding means and to generate a signal to control the controlled function provided that said control signal from said level detector is present for at least a predetermined time period, thereby avoiding false activation of the controlled function due to transient noise.

The present invention may provide a button that is aesthetically pleasing in appearance and use, highly reliable, is low in cost and is not activated by extreme environmental changes.

Finally, and most importantly, the present invention is directed to a phase shift monitoring, capacitive sensing button that avoid false activation of the button by residual impedance and external influences, such as temperature change, cleaner residue build-up and other deposits.

The preferred "constant pressure" embodiment achieves this by compensating for the exemplary fluctuations by setting a threshold for activation higher than any normal fluctuations. Additionally, the present invention avoids false activations by noise transients, including those due to EMI and RFI by delaying the activation of the button, and the associated operative signal that causes it to be activated, by an appropriate amount of time, such as, for example, a time period of the order of about one hundred (100 msec.) milliseconds.

Testing has shown that any set pulses caused by exemplary, extreme environmental changes typically do not last longer than one hundred (100 msec.) milliseconds with an input resistance of, for example, one (1 MΩ) Mega-ohms.

Further testing with the input resistor set to, for example, two hundred and sixty-one (261 kΩ) kilo-ohms resulted without any set pulses caused by extreme environmental conditions. From these results a delay "on" time of the order of about one hundred (100) milliseconds is deemed to be appropriate.

Benefits of the invention include the facts that the button is heat resistant, EMI resistant, RFI resistant, ESD resistant and is capable of providing light and/or other feedback.

The invention may be practised in a wide variety of applications, including but not restricted to, elevator car call or control buttons, utilizing known technology, in the light of the teachings of the invention, which are discussed in detail hereafter.

An embodiment of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is an exploded, perspective view of an exemplary solid state push button.

Figures 2A and 2B are interconnected schematic diagrams of the preferred circuit for the button system of the present invention with constant pressure characteristics, with the two schematics being connected in the "Delay/Dwell Timer" block at the "SET" line.

As can be seen in Figure 1, the exemplary "solid state button" (SSB) 10 of the present invention preferably includes a non-moving, capacitive sensing button surface 1, that can be used, for example, as a call button in the car operating panel (COP) and/or hall fixtures of an elevator system. The SSB is capable of capacitively sensing a human touch, preferably providing both visual feed back (illumination) to the button pusher, as well as communication to the operational control of the elevator system through, for example, a remote station interface that the button has been actuated, so that the system accordingly can react.

The exemplary button of Figure 1 includes the non-moving button element 1 fitted within a light ring element 2, in which ring is carried a circular array of light emitting diodes (LEDs) 3 at its bottom. A printed circuit board 4, into which the light ring element 2 is pin inserted, is carried on the back side of the button elements 1, 2, and is held to the button elements by a bracket 5 and rear bolt 6.

The interconnecting bolt or stem 7 has a front, threaded, male end 7A, which is screwed into the back side of the button surface 1, and a rear, threaded, male end 7B, which is screwed into the front end 6A of the rear bolt 6 with a lock washer 7C. The interconnecting bolt 7 extends through a center, circular opening (unseen) in the light ring element 2 and through an opening in the PC board 4, while the head 6B of the rear bolt 6 fits into a notch in a "U" shaped rear strap 8, which is part of the bracket holder 5. When assembled, the intermediate elements of the button assembly 10 are held in compression between the button surface 1 and the head 6B of the bolt 6.

The bracket 5 includes a series of peripherally spaced, lateral extensions 9 through which screw pins 9B are placed for fastening the button assembly 10 to a face plate or panel. When so fastened, the only elements of the button assembly 10 which are seen by the user is the non-moving, circular button surface 1 surrounded by the translucent ring 2A, which is lit up by the internally contained LEDs when the button is actuated.

It is noted that the touch button elements of Figure 1 are basically symmetrical about their longitudinal center-line, except for the PC board and its associated holder.

The printed circuit board 4 carries on it the electronic components and circuitry which perform the SSB monitoring functions of the present invention.

The primary difference between the preferred "constant pressure" solid state button (CPSSB) and an "auto balancing" solid state button (ABSSB) is that an ABSSB has an auto balancing feature. The purpose of an auto balancing feature is to automatically accommodate for static changes in components, packaging and the environment, while maintaining a relatively high sensitivity to sensing when the button actually has been actuated. Due to the basic operation of auto balancing, an ABSSB is not a pure, "constant pressure" type button and, in the exemplary application of an elevator system, would not be applied to, for example, "door open," "door close" and other applications requiring a pure constant pressure (CP) feature. In contrast the CPSSB module according to the preferred embodiment can be used, if desired, for all applications in the elevator system except the alarm button, which has special requirements.

If a button touch is constantly maintained for, for example, one hundred (100 msec.) milliseconds, the button module 10 will turn "on" its output and illumination long enough to be read and controlled by the operational control system without loss of the call or illumination. The illumination input preferably is controlled by the operational control system. The illumination control of the CPSSB can also be used as an output when applied to other systems.

The basic functions of a CPSSB are as follows:

- Power
- Oscillator
- Phase Shift To Pulse Width Converter
- Integrators
- Level Detector
- Electrostatic Discharge (ESD) Protection
- Delay/Dwell Timer
- Output Control
- High Out
- Illumination Current Regulator

- POWER -

The power aspects of the preferred embodiment represents a standard approach and its operation (and many alternatives thereto) are known to those of ordinary skill.

- OSCILLATOR -

The oscillator generates, for example, a square wave of an appropriate cycle. The threshold voltage to the non-inverting input of comparator U1A is set by resistors R2 & R3, and the state of the output of U1A, which controls the hysteresis resistor R4. The "on" state threshold is higher than the "off" state threshold.

The oscillator is controlled by the charging and discharging of capacitor C1. When comparator U1A is in the "on" state, capacitor C1 will charge to the "on" state threshold, and, as a result, the comparator will turn "off ". Conversely, when comparator U1A is in the "off" state, capacitor C1 will discharge to the "off" state threshold, and, as a result, the comparator will turn "on".

This is standard oscillator circuitry, and its operation and various alternatives are known to those of ordinary skill.

- PHASE SHIFT TO PULSE WIDTH CONVERTER -

The phase shift to pulse width converter functions as follows. The oscillator is connected to the non-inverting input of U1C. When the oscillator is high, the output of U1C is released, providing the rising edge of a pulse. The inverting input of U1B monitors the phase shift of the oscillator through resistor R7 across the button input impedance. (The factors which contribute to the button input impedance are the capacitor C3, the ESD protection circuit and what is applied to or acquired by the button face).

When the voltage at the inverting input of U1B reaches the threshold voltage on the non-inverting input, the output of U1B is pulled to common, at the falling edge of the output pulse of the phase shift to pulse width converter.

There is always a pulse, even without anything applied to the button face 1. The pulse is due to the impedance of capacitor C3, the ESD protection circuit and any residuals in the circuit.

Capacitor C3 is used to prevent any DC voltage from being placed on the button face. The value of the capacitor C3 should be significantly larger than the capacitive sensitivity to be obtained.

The larger the value of the resistor R7, the larger the phase shift is for a given input impedance, including the effects of resistance and noise. The value of the resistor R7 preferably is chosen to generate as large a phase shift as possible from the input.

- INTEGRATOR -

The pulse from the "phase shift to pulse width converter" is fed into a R-C integrator. The integrator converts the pulse into a DC voltage. The DC voltage is equal to the duty cycle of the pulse multiplied by "Vcc," the regulated supply voltage.

- LEVEL DETECTOR -

The purpose of the level detector is to activate the button as long as the voltage on the integrator exceeds the fixed threshold. The integrator voltage being compared to a fixed threshold is what makes this a constant pressure (CP) device.

Several factors contribute to the setting of the threshold set by the resistors R13 and R14. The threshold is set to allow for component tolerance variations within the specified working temperature range. The sensitivity of the button set by the threshold may be set to, for example, forty (40 pF) picofarads with nominal component values and should be no less than the projected "worst case" scenario.

- ELECTROSTATIC DISCHARGE (ESD) PROTECTION

The primary part of the electrostatic discharge (ESD) protection circuit is the spark gap SG1. In the event of an ESD the spark gap will activate and provide a low impedance path to earth via connector J4-1.

Connector J4-1 preferably is connected to the face plate of the button with a short wire. In hall fixture applications the face plate should be connected to the masonry box with, for example, an insulated flat braided conductor. The masonry box in turn should be bonded to building steel through wiring conduit or a flat braided conductor to the closest building steel.

The spark gap is a relatively slow device, and, therefore, the zener diode CR1 is used to limit any incoming voltage to, for example, thirty volts (30V). The purpose of resistor R1 is to limit the current through the zener diode CR1 and absorb the major portion of the energy.

Resistor R1 may be selected to be of carbon composition due to their pulse energy handling capability and size.

J4 may be a separate connector from J1 to maintain, for example, a 6 mm (0.25") spacing between the chassis ground and the rest of the circuit. The relatively large spacing is required to prevent uncontrolled arcing on the PC board during an ESD. During an ESD the potential of J4 will rise due to the very high frequency components of the ESD and the inductance of the chassis ground lead.

Appropriate spacing is required from the button connection to the button face. The electrical connection to the button face can be achieved with, for example, appropriate wire soldered into the PC board and a ring terminal to the intermediate button stem or interconnecting bolt 7

(See Fig. 1), which bolt holds and electrically connects the button face and the PC board.

- CONSTANT PRESSURE SSB DELAY/DWELL TIMER -

The purpose of the delay/dwell of the CPSSB timer is for erroneous signal rejection and to ensure that, once an input to the button face has activated the button, a call will be registered regardless of subsequent changes to the input.

The erroneous signals of primary concern are those which could be caused by heat or other like extreme environmental changes. Testing has shown that any set pulses caused by extreme environmental changes typically do not last longer than one hundred (100 msec.) milliseconds with an input resistance (R7) of, for example, one (1 MΩ) Mega-ohm.

Further testing with the resistor R7 set to, for example, two hundred and sixty-one (261 kΩ) kilo-ohms resulted without any set pulses caused by extreme environmental change. From these results a delay "on" time of, for example, one hundred (100) milliseconds is deemed to be more than adequate for exemplary purposes.

The delay "on" time is initiated upon the release of the level detector's output from common, allowing capacitor C6 to charge through resistors R17 and R18. Once the voltage on C6 reaches the "inactive" threshold the output of comparator U1D is pulled to common, activating the output control. The threshold voltage to the non-inverting input of comparator U1D is set by resistors R20 & R21 and the state of the output of U1D which controls the hysteresis resistor R22. The time required to charge C6 provides the delay "on" time.

If the input to the button face is removed prior to the output of U1D being pulled to common the delay "on" time will be quickly reset. As a result of the input to the button face being removed the output of U1C is pulled to common, providing a discharge path for C6 via CR3, Q6 and R16. Since the output of U1D is not pulled to common, transistor Q6 will be active during the discharge of capacitor C6. The activation of transistor Q6 effectively removes resistor R18 from the discharge path of C6, allowing the delay "on" time to be quickly reset.

The dwell "on" time begins when the input to the button face is removed after the output of U1D is pulled to common. The voltage across capacitor C6 is discharged through resistors R16 and R18, providing the dwell "on" time. Once the voltage across C6 reaches the "active" threshold the output of comparator U1D is released from common, deactivating the output control.

Resistor R16 limits the discharge current to protect the output of U1C. Resistors R17 & R16 create a voltage divider to which the capacitor C6 will discharge. Resistor R17 was selected to set the voltage of the divider lower than the "active" threshold voltage.

Diode CR7 protects transistor Q6 by limiting the emitter-to-base voltage. When the output of U1C is released and U1D is pulled to common; a voltage divider is created by resistor R17, diode CR7 and resistor R19. This voltage divider sets the voltage on capacitor C6, while the button is being held in the active state. The difference between the voltage divider and the "active" threshold level provides the "dv" or difference in voltage for the dwell time.

Diode CR3 prevents leakage current through Q6, which would decrease the delay "on" time provided by the charging of capacitor C6.

- OUTPUT CONTROL -

The output control provides the active pull to common required by the "high out" and "illumination current regulator" functions.

Transistor Q1 of the output control provides the signal inversion required between the output of comparator U1D and the output driving transistor Q2.

Transistor Q2 was chosen to have the current rating required to drive the "high out" and "illumination current regulator" functions.

- HIGH OUT -

The button assembly 10 is designed to interface to a remote station module in an elevator system. The output to the module is required to be an active high level. The high level is provided through resistor R28, when the transistor Q3 is driven into saturation by transistor Q2, pulling resistor R27 to common.

Resistor R28 is a current limiting resistor, which protects the transistor Q3 in the case of an accidental shorting of the output to ground.

- ILLUMINATION CURRENT REGULATOR -

The illumination is controlled by the button 1 through transistor Q2 or the module through connector J1-2. The illumination is comprised, for example, of two external strings of LEDs being fed by dedicated current regulators through connectors J2 and J3. The current through each string is regulated to, for example, thirty (30mA) milliamps, by controlling the voltage across the resistors R30 and R31 with zener diode CR4.

The value of resistor R29 was selected to provide the proper current dependent voltage across diode CR4.

The signal diode CR5 is used to isolate the high level output from the illumination control of the remote station module. This isolation allows the operational controller to be signaled, when the button is released.

Due to the minimum input voltage requirement of, for example, twenty and four-tenths volts DC (20.4 VDC) the nine light ring LEDs were divided into two strings.

- CIRCUITRY DETAILS -

Of course the circuits shown and described are exemplary and subject to great variation. The specific values of each of the resistors, capacitors and diodes are not key to the invention and many workable values of them are available and known to those of ordinary skill.

The exemplary solid state button assembly described in detail above is designed to be applied in a hall fixture and car operating panel (COP) of an elevator, although, of course, many other uses and applications are possible. The exemplary unit described is a low cost, easily replaceable device, taking, for example, five (5) minutes to replace.

Although this invention has been shown and described with respect to a preferred embodiment thereof, it should be understood by those skilled in the art that various changes in form, detail, methodology and/or approach may be made without departing from the scope of this invention.

Claims

1. A capacitive sensing touch button (10) for controlling a function, said button (10) comprising:

a button surface member (1) for receiving a reference signal, said button surface member (1) outputting a signal shifted in phase, relative to the reference signal, upon contact of said button surface member (1) by a user;

an oscillator to provide the reference signal to said button surface member (1), said oscillator having a predetermined duty cycle;

a phase shift to pulse width converter to convert the phase-shifted signal into a pulse width based on the amount of the phase shift relative to the reference signal;

means for avoiding false activation of the controlled function due to residual impedance and/or external influences at said button surface member (1), said avoiding means receiving the output of said phase shift to pulse width converter;

characterised in that said avoiding means further comprises an integrator to convert the pulse width into a dc voltage; and

a level detector to output a control signal when the dc voltage is greater than a predetermined threshold voltage;

and in that said button further comprises delay means to receive an output signal of said avoiding means to generate a signal to control the controlled function provided that said control signal from said level detector is present for at least a predetermined time period, thereby avoiding false activation of the controlled function due to transient noise.

2. A capacitive sensing touch button according to claim 1, wherein said phase shift to pulse width converter comprises a diode.

3. A capacitive sensing touch button according to claim 1 or 2, wherein said delay means comprises:

a transistor (Q6) having an emitter operatively connected to said control signal from said level detector;

a first resistor (R18) and first diode (CR3) in series connection between said emitter and the collector of said transistor, wherein the cathode of said first diode (CR3) is connected to said collector;

a second diode (CR7) having an anode and a cathode operatively connected between said emitter and the base, respectively, of said transistor; and

a comparator (U1D) having a first input operatively connected to said anode of said first diode (CR3), said first input further being operatively connected to ground via a first capacitor (C6), and a second input operatively connected to an RC network having a predetermined time constant wherein the output of said comparator (U1D) controls the controlled function, provided that said control signal from said level detector is present for at least a predetermined time period, wherein said predetermined time period is based on said time constant.

4. The capacitive sensing touch button according to any preceding claim wherein said touch button (10) further includes electrostatic discharge protection circuitry operatively connected between said button surface member (1) and said phase shift to pulse width converter, said protection circuitry comprising:

a spark gap (SG1) connected between said button surface (1) and a first grounding path;

a resistor (R1) having a first terminal connected to said button surface member (1) and a second terminal connected to said phase shift to pulse width converter; and

a Zener diode (CR1) connected between said second terminal of said resistor (R1) and a second grounding path, wherein said first and second grounding paths are separate.

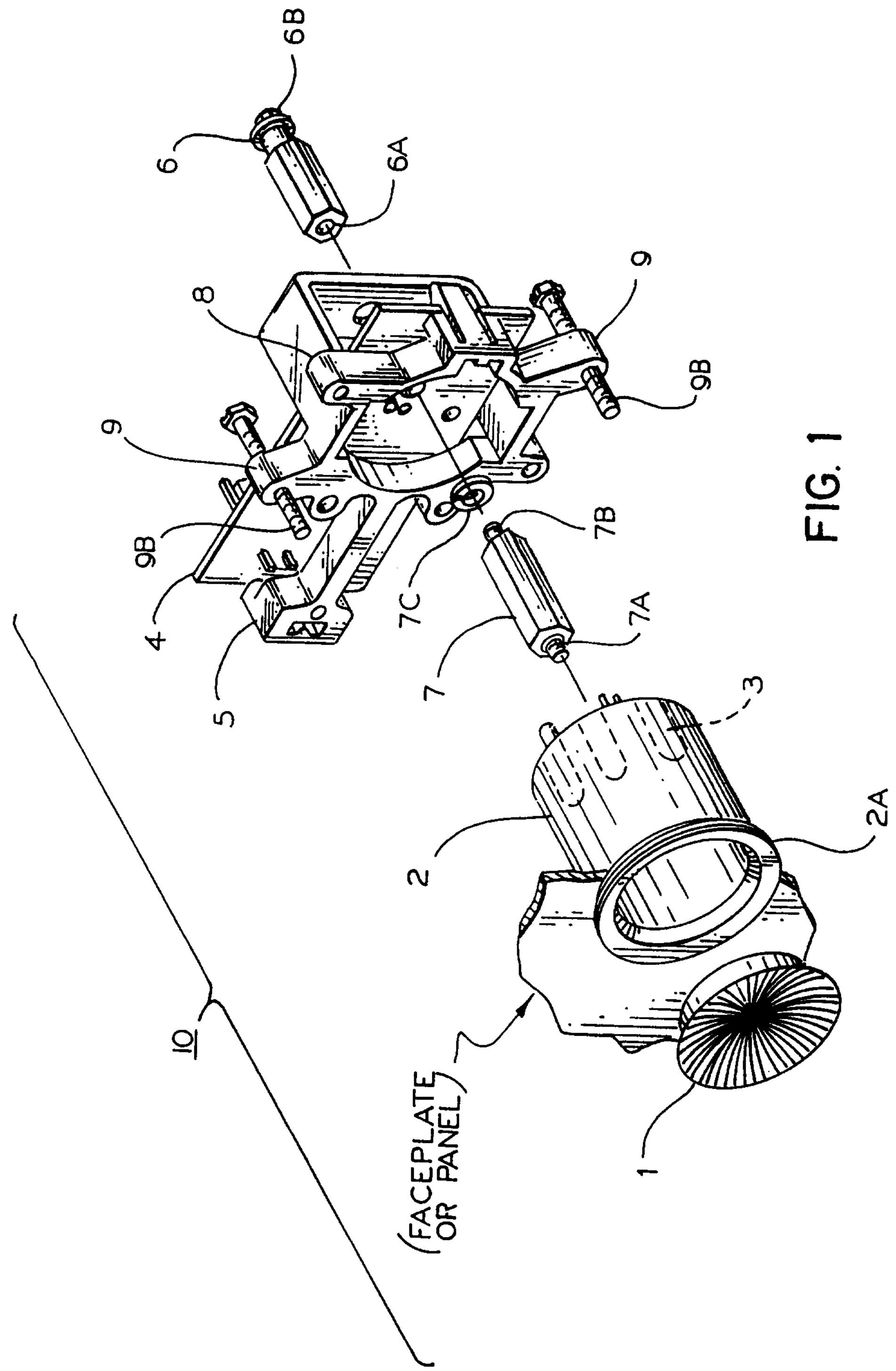

FIG. 1

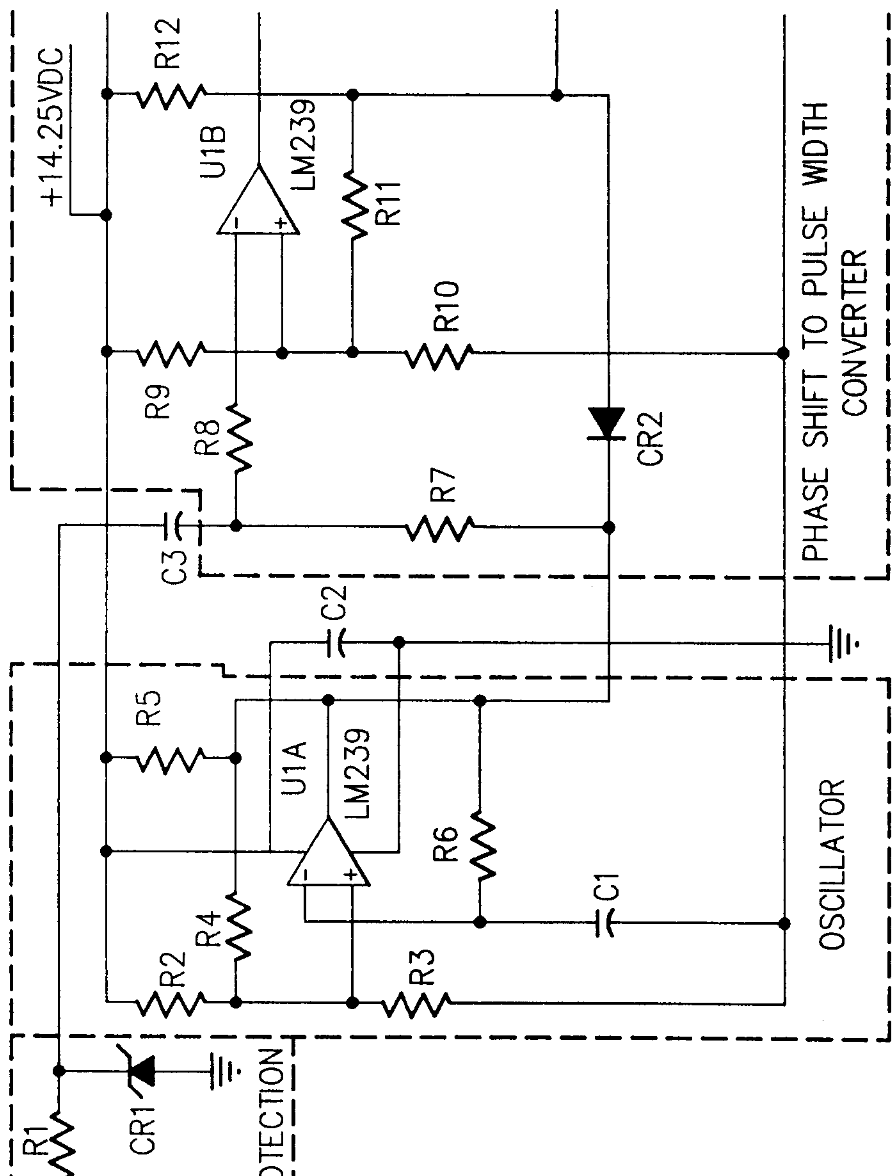

FIG.2A(a)

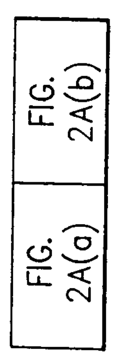

FIG.2A

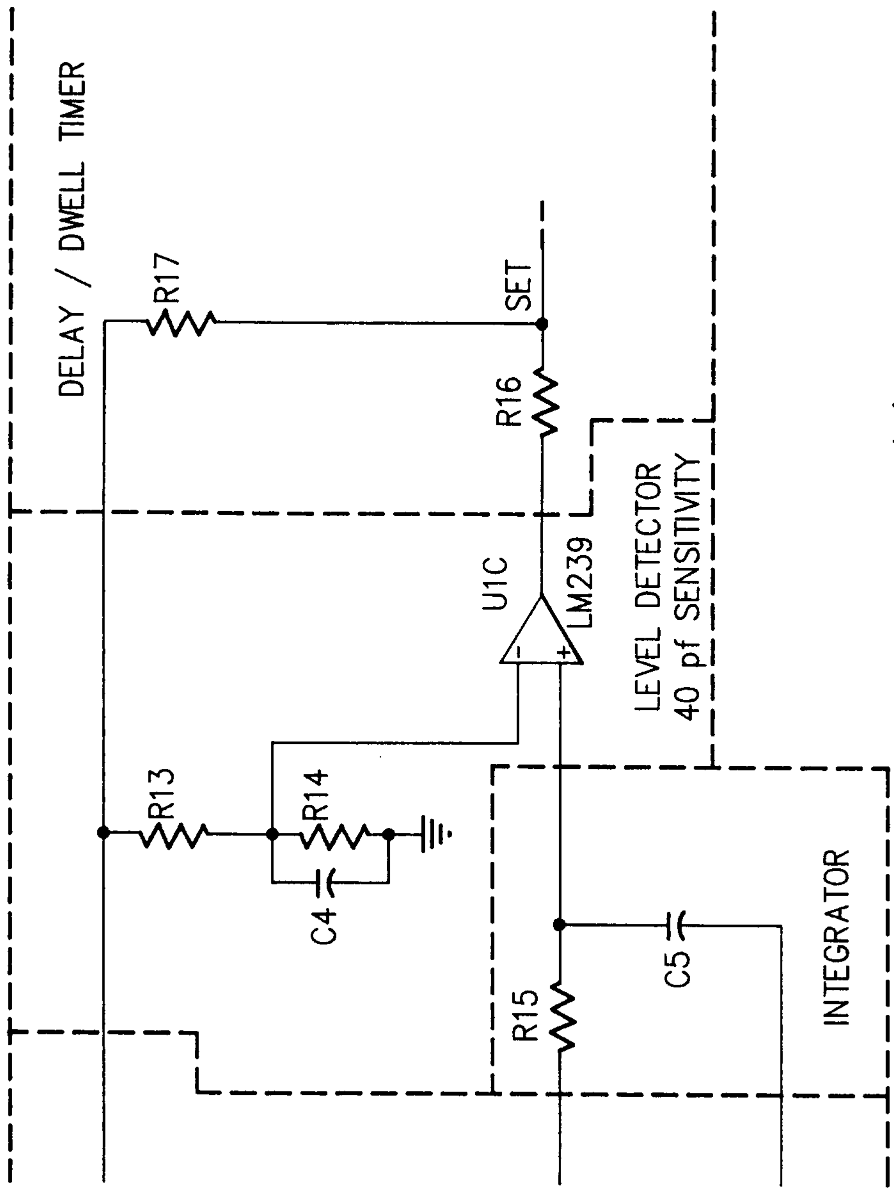
DELAY / DWELL TIMER
R17
SET
R16
U1C
LM239
LEVEL DETECTOR
40 pf SENSITIVITY
R13
R14
C4
C5
R15
INTEGRATOR

FIG.2A(b)

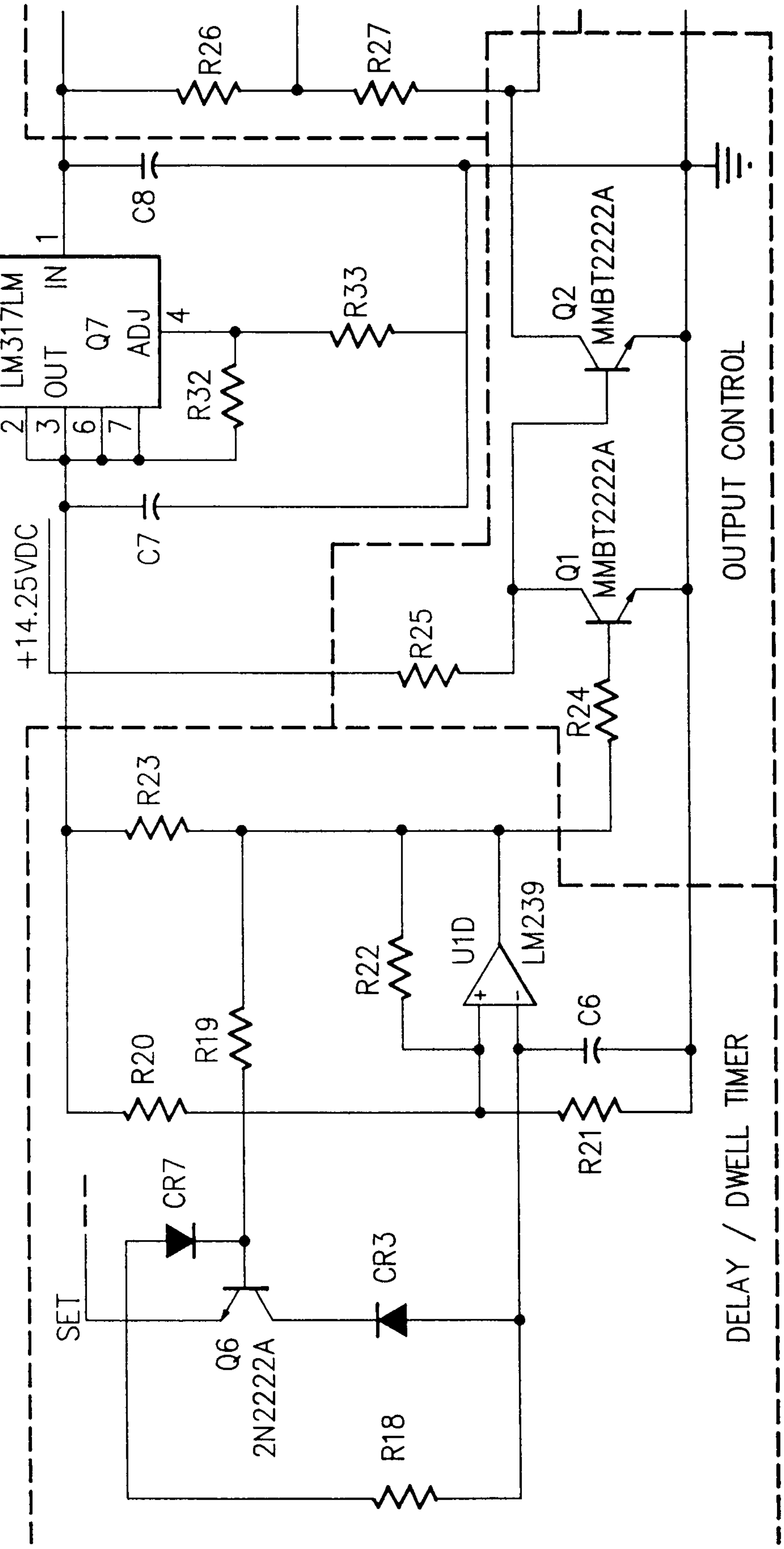
R26
R27
C8
1
LM317LM
IN
OUT
Q7
ADJ
4
2
3
6
7
R33
R32
C7
+14.25VDC
Q2
MMBT2222A
Q1
MMBT2222A
OUTPUT CONTROL
R25
R24
R23
R22
U1D
LM239
C6
R20
R19
R21
DELAY / DWELL TIMER
CR7
CR3
SET
Q6
2N2222A
R18

FIG.2B(a)

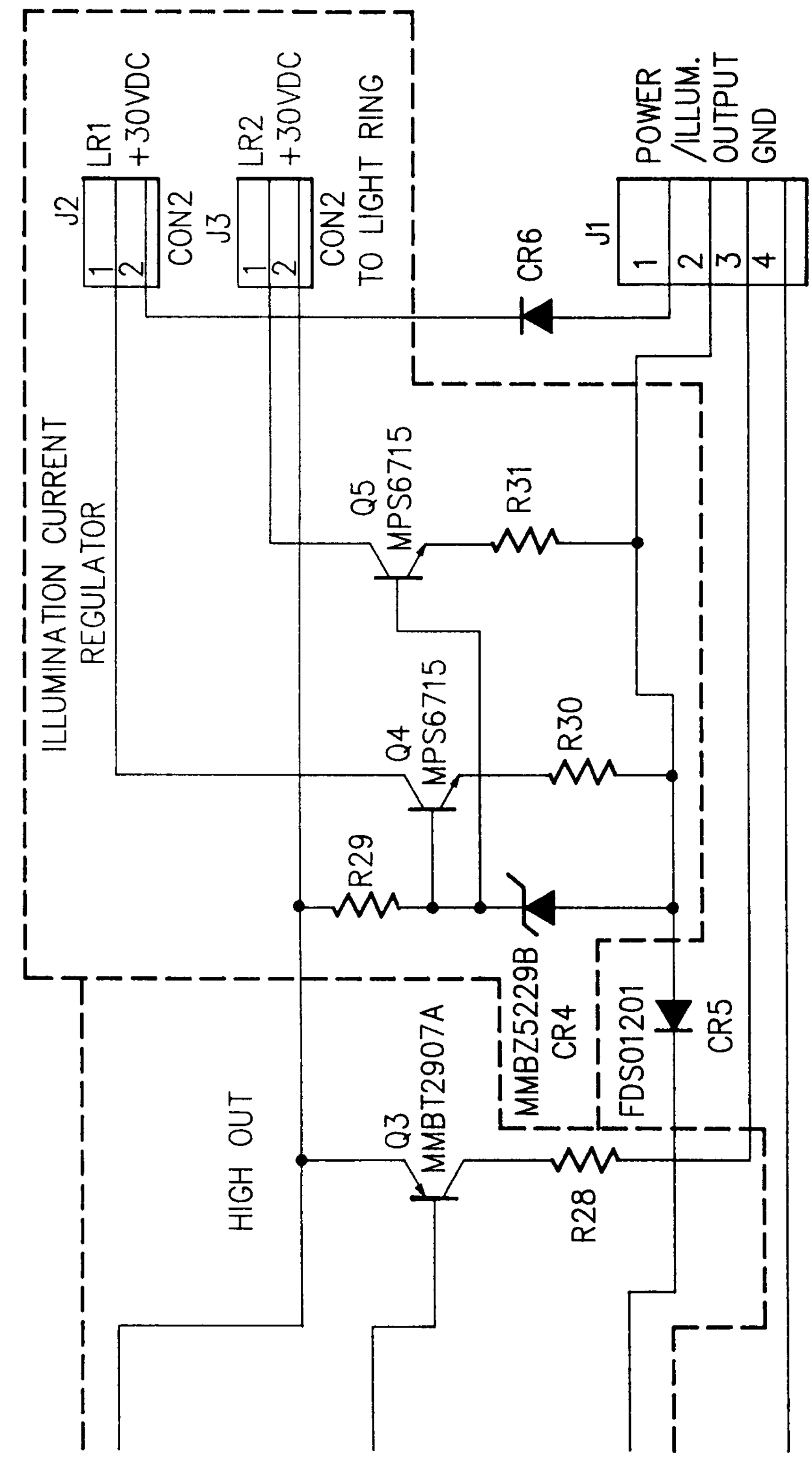

FIG.2B(b)

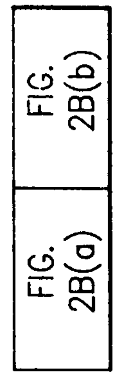

FIG.2B